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New technologies for the assessment of blood pressure responses were evaluated to determine if they contribute to increased reliability and validity of detection of deception. The traditional cardio measure was compared with two devices (Finapres and Cortronic) designed to measure blood pressure accurately, unobtrusively, and continuously on each beat of the heart. Electrodermal measures were also taken. Two different experimental paradigms were used--the orienting reaction and the "Stim" test, while continuous physiological measurement was taken on a traditional cardio measure, an electrodermal measure, and both the Finapres and the Cortronic automated blood pressure devices. Data from 28 female and 14 male subjects are reported. In the first experiment subjects were presented with 15 repeated 800-Hz tones at 70 db, and their orienting reactions were recorded. In the second part of the experiment, subjects were given a Stim test in which they were to choose a card from a deck and then lie to the questioner about the card that was selected. The results indicated that the electrodermal measure showed the expected patterns of orienting reaction elicitation and habituation, but that none of the cardiovascular measures yielded any evidence of a blood pressure orienting response. Further, it was observed, that electrodermally labile subjects showed larger electrodermal orienting responses and a habituation rate than electrodermally stabile subjects. On the Stim test the electrodermal measures significantly discriminated between lies and truth ($p < .01$), although there was no effect of lability. This suggests that although electrodermal lability affects orienting responses it does not affect the discrimination of deceptive from truthful responses. There were no significant findings for any of the blood pressure measure on the Stim test.

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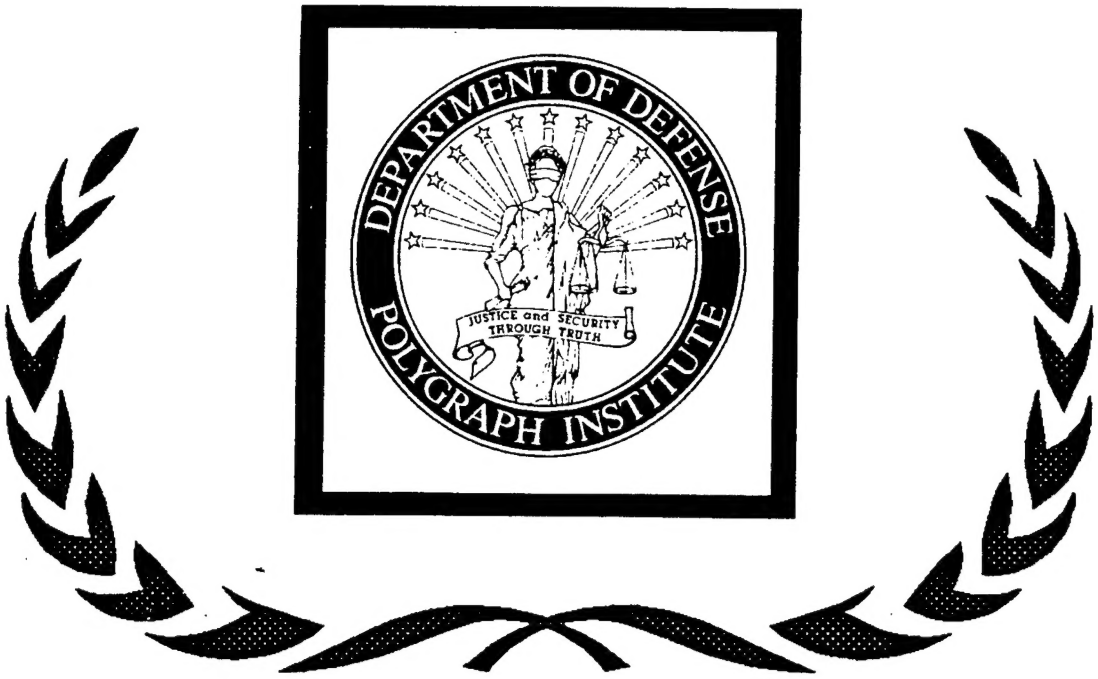

A Comparison of the Traditional Polygraphic Cardio Measure with Two New Techniques for Continuous Blood Pressure Assessment

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January 1997

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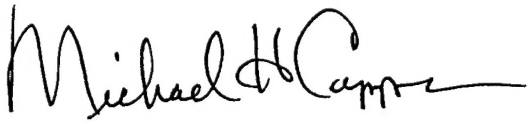
Director's Foreword

The blood pressure cuff is routinely used to measure cardiovascular activity during psychophysiological detection of deception examinations. The cuff, which is usually placed on the upper arm, reduces circulation throughout the arm. Most examinees find this to be uncomfortable and object strongly if asked to tolerate the discomfort for more than a few minutes at a time. Consideration of this discomfort has always been a major factor in determining the number of questions which could be asked during a single data collection period. Elimination of this discomfort would allow the examination length to be increased and additional questions to be asked—possibly improving examination accuracy by supplying more data.

This project was funded to evaluate two possible alternatives to the traditional blood pressure cuff, the Finapres and Cortronic blood pressure measurement systems. Both systems are purported to be more comfortable than the traditional blood pressure cuff. Finding a replacement for the blood pressure cuff could be a productive first step toward improving the polygraph instrument.



Michael H. Capps
Director

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Abstract

KATKIN, E. L. A comparison of the traditional polygraphic cardio measure with two new techniques for continuous blood pressure assessment. January 1997, Report No. DoDPI97-R-0005. Department of Defense Polygraph Institute, Ft. McClellan, AL 36205-5114.--This project evaluated new technologies for the assessment of blood pressure responses in order to determine if they may contribute to increased reliability and validity of detection of deception. The traditional cardio measure was compared with two new devices (Finapres and Cortronic) designed to measure blood pressure accurately, unobtrusively, and continuously on each beat of the heart. Electrodermal measures were also taken. Two different experimental paradigms were used--the orienting reaction and the "Stim" test, while continuous physiological measurement was taken on a traditional cardio measure, an electrodermal measure, and both the Finapres and the Cortronic automated blood pressure devices. Data from 28 female and 14 male subjects are reported. In the first experiment subjects were presented with 15 repeated 800-Hz tones at 70db, and their orienting reaction were recorded on all channels. In the second part of the experiment, subjects were given a Stim test in which they were to choose a card from a deck and then lie to the questioner about the card that was selected. Again, physiological measures were obtained continuously. The results indicated that the electrodermal measure showed the expected patterns of orienting reaction elicitation and habituation, but that none of the cardiovascular measure yielded any evidence of a systolic or diastolic blood pressure orienting response. Further, it was observed, as expected, that electrodermally labile subjects showed larger electrodermal orienting responses and a faster habituation rate than electrodermally stabile subjects. On the Stim test the electrodermal measures significantly discriminated between lies and truth ($p < .01$), although there was no effect of lability. This suggests that although electrodermal lability affects orienting responses it does not affect the discrimination of deceptive from truthful responses. There were no significant findings for any of the blood pressure measure on the Stim test.

Key words: blood pressure, electrodermal response, orienting response, stim test, automated blood pressure assessment, finapres, cortronic, detection of deception

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The goal of this project was to evaluate new technologies for the assessment of blood pressure responses in order to determine if they may contribute to increased reliability and validity of detection of deception. The rationale for this project was based upon current use of the so-called "cardio" channel, a measure of relative changes in blood pressure and/or volume recorded from the brachial artery. The tracing recorded on the cardio channel includes some aspects of heart rate, some aspects of relative blood pressure, and some aspects of blood volume shifts. Because of the complexity of the underlying contributors to the cardio measure, and because absolute quantification of the changes is not possible in the cardio channel, this measure leaves something to be desired with respect to precision of measurement and with respect to indexing a specific underlying psychophysiological response.

For most of modern psychophysiological history, however, there was no better technology with which to get continuous measures of blood pressure; traditional auscultatory occlusive procedures can, at best, yield one measure every 30 seconds, and invasive indwelling catheters are neither practical nor ethical for detection of deception. During the past decade new technological developments have appeared, allowing for the continuous assessment of blood pressure (systolic, diastolic, and mean arterial) on each beat of the heart, using non-invasive, auscultatory techniques (Orlebeke, Mulder, & Van Doornen, 1985).

These methods have been incorporated into the design of two instruments, one called the "Finapres" (manufactured by the Ohmeda Corp. and the other called "Cortronic" (manufactured by Cor Medical Corp). The instruments yield putatively similar data sets, but they are based on different measurement algorithms and they are implemented differently. The Finapres instrument reads blood pressure from the middle or distal phalange of the finger, responding to changes in volume in the small arterioles and capillaries of the finger. The Cortronic instrument uses a standard blood pressure cuff placed over the brachial artery, and responds to changes in brachial arterial pressure.

The algorithm that drives the Finapres device utilizes feedback from a photoplethysmographic volume transducer. As blood pressure increases the arterial wall expands, increasing the volume of the finger. The photoplethysmograph detects the increased volume, and a servo-control mechanism adjusts the pressure within the cuff until the original arterial size and blood volume are again reached. Its internal calibration then uses the information about magnitude of adjustment to infer systolic pressure, diastolic pressure, and mean arterial pressure from the pressurized adjustments for each cardiac cycle. The instrument also reports heart rate for each cardiac cycle. Correlations between Finapres assessments and assessments from indwelling catheters are reported to be quite high (Smith, Wesseling, & De Wit, 1985).

The algorithm that drives the Cortronic instrument is somewhat different. This instrument first does a reading of systolic and diastolic pressure using a standard occlusive technique. After that it sets the internal pressure to a fixed level (either 15 or 20 mmHg at the user's choice) during diastole, and the cuff pressure is never adjusted after that. Rather, the cuff, which at 15 or 20 mmHg is substantially below diastolic pressure (and is therefore unobtrusive and does not occlude venous return) is alternately compressed and dilated by the blood flow through the brachial artery on each cardiac cycle. The theory of operation of the Cortronic device is based on the observation that arterial pressures (stresses) and resulting displacements (strains) of an artery segment conform to a non-linear elasticity stress-strain relationship (Abel & McCutcheon, 1979; Bergel, 1961). The Cortronic algorithm uses the systolic, diastolic, and mean arterial pressures obtained from the occlusive measurement as well as a short sequence of displacement waveforms measured at the low cuff pressure to compute a specific elasticity relationship for the relevant range of pulsatile displacements and corresponding pressures of the artery at the monitoring site (brachial artery) for each subject. The algorithm then detects the pulsatile waveforms on each cardiac cycle and by interpolating them in the elasticity curve it infers systolic, diastolic, and mean arterial pressure for each cardiac cycle. This instrument also reports heart rate for each cardiac cycle. Studies of the correlation between Cortronic readings and readings from indwelling catheters indicate that the instrument is quite valid as an index of arterial blood pressure.

The critical difference between the Finapres and the Cortronic instruments is in the different algorithms employed; in addition, the Finapres is slightly more obtrusive than the Cortronic, because the subject is aware of continuous pressure adjustments on the finger tip, whereas the Cortronic instrument, which does not adjust its cuff pressure is less obtrusive. It is also possible that the Finapres may be more subject to movement artifact as the finger is more likely to move than is the upper arm. Presumably, however, both of these instruments provide accurate measures of cardiovascular adjustments to stress, and given the fact that they report absolute levels of pressure, readings from these instruments can be compared across subjects. For that reason it is likely that either or both of these instruments might provide an improvement in the assessment of cardiovascular reactivity to the stress inherent in the detection of deception polygraph examination. Yet, there has been no research to date comparing response characteristics of these two instruments to each other or to the assessment of responses on the traditional polygraphic "cardio" channel.

This project carried out basic experimental evaluations of the cardiovascular response characteristics on the Cortronic, Finapres, and cardio channels, as well as an electrodermal channel, during two different paradigms. The first part of the

experiment examined the elicitation and habituation of the orienting reaction. The second part evaluated responses to a simple "stim" test of the nature typically used in a polygraph pre-examination.

Orienting reaction. The orienting reaction was first noted by Pavlov in his work on classical conditioning of autonomic reflexes in dog. However, much current research and thinking on orienting and attention has been derived from the work of Sokolov (1960, 1963a, 1963b). The orienting response (OR), as Sokolov has conceptualized it, is a generalized response system that possesses autonomic nervous system components; it is elicited by any novel stimulus or change in the environment. Orienting reactions habituate rapidly to repeated stimulation.

With respect to cardiovascular components of orienting, it is usually the case that the OR is characterized by heart rate deceleration (Graham & Clifton, 1966); there is little literature on the blood pressure component of the OR, but it can be assumed that blood pressure ORs should habituate rapidly. A comparison of the traditional cardio response with blood pressure and heart rate responses assessed by the Finapres and the Cortronic would enable an evaluation of the degree to which each of these instruments best reflects the theoretically expected parameters of the OR. Specifically, presenting subjects with repeated presentations of neutral stimuli and evaluating the response characteristics and habituation rates on the three instruments will enable us to discover which instrument most accurately reflects the autonomic components of the response systems.

Much research has been carried out on the effects of stimulus parameters on the elicitation and habituation of orienting responses (Geer, 1966; Maltzman & Raskin, 1965) as well as on the contribution of individual differences in subject characteristics to orienting (Crider & Lunn, 1971; Katkin, 1975). Among the many subject characteristics examined, one that has been observed to be a valuable predictor of OR habituation rate is nonspecific electrodermal activity, or electrodermal lability (Katkin & McCubbin, 1969; Koepke & Pribram, 1966). Nonspecific electrodermal responses are defined as spontaneous fluctuations in electrodermal responses which occur in the absence of external stimulation. Nonspecific electrodermal activity is believed to be an effective monotonic indicator of central nervous system activation (Burch & Greiner, 1960) as well as a valid index of transitory response to stress (Katkin, 1975). For those reasons, in the proposed research subject responsivity will be evaluated as a function of individual differences in their electrodermal lability.

"Stim" test. The second major question explored in this project was the relative utility of the three cardiovascular instruments in detecting deception on a standard "stim" test. In testing for deception, polygraph operators typically employ a

"stim" or "stimulation" test, primarily as a means of convincing the subject that the polygraph examination is accurate. One of the typical techniques used in a "stim" test is the "number" or "card" test. In this test, a subject is asked to select a card from a deck that has numbers written on them, perhaps from 1 to 10. The examiner then questions the subject specifically about the number on the selected card, repeating each of the possible numbers many times. It is expected that when the examiner states the selected number the subject is stimulated more than when the examiner states a neutral number; autonomic responsivity to the selected number is therefore greater than to a neutral number. In some variations of the "stim" test the subject is asked to deny the examiner's suggestion every time, so that when the selected number is offered the subject is required to deceive the examiner by denying it. This simulates the detection of deception examination which normally follows the stim test.

"Stim" tests are known to be useful and reliable, so the use of the three cardiovascular instruments in addition to an electrodermal channel in a typical stim test will add considerably to the evaluation of their relative efficacy for improving the reliability and validity of polygraphic examinations for detection of deception.

Method

Subjects

Subjects were recruited in two ways. Some were students in various psychology classes at State University of New York at Stony Brook in which students were required to participate in research. Others were attracted by signs offering $5 in exchange for their participation in the experiment. A total of 46 subjects were run--32 females and 14 males. Data from 4 of the female subjects had to be eliminated from the data set because of equipment failures during the running of the experiment, leaving 42 subjects.

Apparatus

Four different physiological measuring devices were used--a polygraph to measure electrodermal response (EDR), and three blood pressure monitors. EDR was recorded with two silver-silver chloride electrodes attached to the hypothenar eminence of the nondominant hand (Venables & Christie, 1980). An electrode gel recommended by Fowles, Christie, Edelberg, Grings, Lykken and Venables (1981) was used. These electrodes were connected to a Grass polygraph and the data were stored on paper.

Blood pressure was assessed with three different instruments. One was the Cortronic Model 7000 continuous blood pressure monitor (Cor Medical Corp.). The cuff was placed over the brachial artery on the upper part of each subject's left arm.

The instrument applies 20 mmHg pressure, which does not occlude the artery and allows continuous assessment of systolic blood pressure, diastolic blood pressure and mean arterial pressure during each cardiac cycle. A second continuous blood pressure monitor, the 2350 Finapres Monitor (Ohmeda), took recordings via a cuff placed between the first and second joints of the subject's left middle finger. A third cuff was placed over the brachial artery of the subject's upper right arm and attached via hoses to a Model PT5 volumetric low pressure transducer on a Grass polygraph. The cuff was inflated to a constant pressure of 40 mmHg for the duration of the experiment. The signal from the transducer was run through two Grass pre-amplifiers in order to guarantee a readable signal amplitude. A computer stored the data from all three blood pressure devices.

Procedure

Upon arriving at the lab, subjects were asked to read and sign a consent form. Then they were brought into an 8' x 9' Industrial Acoustics Company sound attenuating chamber and seated in a comfortable chair. Subjects were fitted with the EDR electrodes, and the three blood pressure cuffs. The experimenter then left the chamber and activated the computer which controlled the presentation of instructions from that point on.

The computer first directed subjects to relax for a few minutes. Subjects sat quietly for 5 minutes, during the last 2 of which baseline recordings of blood pressure and EDR were taken. The baseline period was followed by the orienting response task. This task involved presenting subjects with a series of 70 db, 800 Hz tones and recording their physiological responses for the next 15 seconds. After each trial, there was a random interval of 1-5 seconds before the next tone. There were 15 orienting trials in all.

After the orienting task was completed, the experimenter deflated all blood pressure cuffs and then give the subject instructions on how to perform the stim task. The subject was shown five cards (one of each type: square, circle, star, plus sign, or wavy lines) and the experimenter told the subject what each card was called. (i. e., "This is the star," "This is the wave," etc.). The subject was then instructed to pick one card and place it in an envelope without showing it or the other four cards to the experimenter. Once the card was selected, the subject was told that he or she would be asked questions by the computer about what card he or she had selected (i. e., "Was it the square?", "Was it the star?", etc.). The subject was instructed to answer "No" to each question, whether or not the question referred to the card the subject had picked. When the experimenter was convinced that the subject understood the instructions, the experimenter left the chamber and the blood pressure cuffs were re-inflated.

There were 25 trials of the stim test. Each of the 5 cards was asked for a response 5 times. Questions were presented in 1 of 2 orders, determined randomly prior to the start of the experiment. After each question, the physiological measures were taken for 15 seconds. After the stim test, the subject was de-instrumented, debriefed. paid or given credit, and dismissed.

Results

Orienting Response

The data from all physiological measures of the orienting response were analyzed by a mixed design 2 (sex) x 2 (electrodermal lability) x 5 (trial blocks of three trials each) analysis of variance in which sex and lability were between-subjects variables and trial blocks was a within-subjects variable (Winer, 1962). Subjects were assigned to the labile or stabile category based upon a median split of the distribution of nonspecific electrodermal responses for all subjects during the last minute of baseline.

Electrodermal response

The analysis of the data yielded a significant main effect of electrodermal lability, $F(1, 38) = 25.61$, $p < .0001$; a significant main effect of trial blocks, $F(4, 152) = 16.63$, $p < .0001$, a significant lability x trials interaction, $F(4, 152) = 4.47$, $p < .005$, and a significant sex x trials interaction, $F(4, 152) = 3.44$, $p < .01$. These results are displayed in Figs. 1 and 2, in which it may be seen that labile subjects showed a larger orienting response than stabile subjects at all times, and also showed a faster habituation rate than stabile subjects. The sex x trials interaction (Fig. 2) suggests that females started with a slightly larger response than males and then habituated somewhat more quickly.

Blood Pressure Responses

None of the blood pressure indexes yielded any significant evidence of a systolic or diastolic blood pressure orienting reaction; in the absence of evidence of a response, obviously no evaluation of habituation was possible. There were no interactions with lability or sex.

Stim Test

Electrodermal responses. The analysis of the electrodermal responses associated with the 5 lie responses vs. the 20 truthful responses yielded a significant main effect for lies vs. truth, $F(1, 38) = 7.46$, $p < .01$, but no main effect of lability or sex and no interaction of lability or sex with truth telling. The mean amplitude of EDR on lie responses was 1.09 microsiemens and the mean for truthful responses was 0.76 microsiemens.

Blood pressure responses. Again no significant differences were found on systolic or diastolic blood pressure for lie versus truthful responses.

Discussion

The results of this experiment provide strong support (as usual) for the utility of the electrodermal response as an index of psychophysiological detection of deception. The results do not speak well for the utility of the traditional cardio measure or for any of the newer, more expensive, and technologically advanced indexes of continuous blood pressure for this application. In physiological terms it is likely that this should have been predictable. If a subject who is lying shows sympathetic arousal, it is likely that a combination of beta adrenergic and alpha adrenergic activation of the peripheral vasculature will act to adjust the peripheral resistance of the vessels to accommodate the increased cardiac output induced by the beta-adrenergic myocardial activation to maintain homeostatic regulation of blood pressure. In brief, these data support the view that while a non homeostatic index of sympathetic arousal (EDR) may be a useful index of psychophysiological detection of deception, indexes which are tied more directly to homeostatic regulatory activity of the autonomic nervous system (i.e., blood pressure) may not accurately index transitory increases in sympathetic arousal such as those elicited in this study.

Future studies should be addressed to the analysis of indexes of beta-adrenergic arousal that may be more sensitive than EDR. Such indexes are systolic time intervals such as cardiac pre-ejection period and left ventricular ejection time as well as inotropic indexes of myocardial adrenergic arousal such as the Heather index.

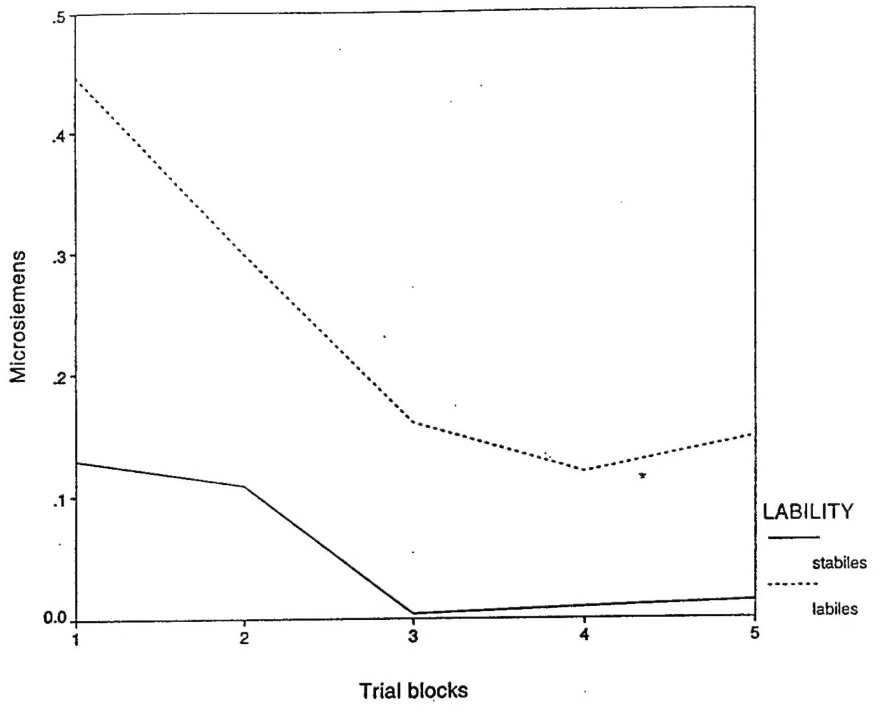

Figure 1. Mean magnitude of orienting response (OR) across five trial blocks of three trials each for labile and stabile subjects.

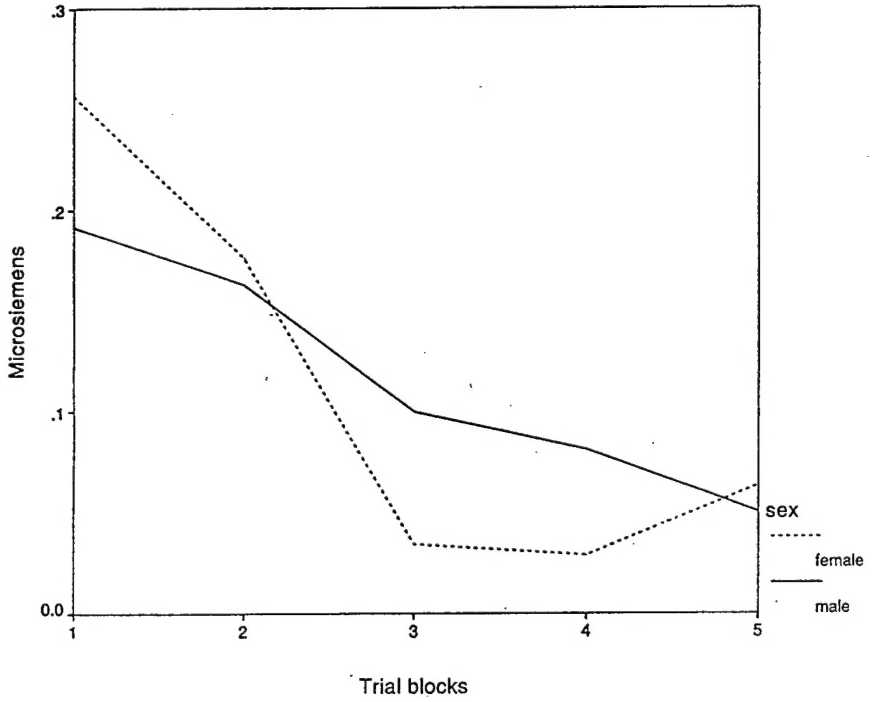

Figure 2. Mean magnitude of orienting response (OR) across five trial blocks of three trials each for male and female subjects.

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